

Table 1. Analytical constituents for project. [Rank, H-high, M-medium, L-low]

Constituent	Description	Analysis purpose	Rank(h,m,l)	Site purpose
Field values	water temperature, pH, conductance, turbidity, ORP, DO	Standard purge monitoring parameters for sample stability criteria. Hydrogen ion activity and D.O. state.	H	Standard data and allow for comparison to previous field parameter values.
Dissolved ferrous iron	Fe2+	Redox identification, iron available for oxide reactions. U+6 can be locked up in some cases with oxide formation.	H	Not collected at site but easily obtainable data.
Dissolved oxygen	DO	Additional measurement of D.O. as a check on probes.	H	Check measurement on D.O. probe.
Alkalinity	Alkalinity as CaCO3	Anion and cation balance. Understand carbonate and bicarbonate reactions. U+6 mobile under high carbonate concentrations in some cases. Alkaline leaching process was employed at tailing sites.	H	Important constituent for charge balance and to understand carbonate concentrations.
Total organic carbon	TOC	General carbon availability gauge. Microbial-mediated reduction of uranium can be stimulated by the availability of an electron donor.	M	Limited data available at the site but provides useful information on electron donor availability.
Major anions	Br, Cl, F, SO4	Major anions for geochemical reactions and water type.	H	Identify water type.
Major cations	Ca, Mg, Na, K	Major cations for geochemical reactions and water type.	H	Identify water type.
Trace elements	224 trace elements	Includes important elements such as selenium and molybdenum; CO-CONTAMINANTS.	H	Required constituents.
Nitrogen	NO3 + NO2 as N, NO2 as N	High nitrate concentrations have been associated with the site. Nitrate reactions can affect uranium concentrations. Presence of nitrate oxidized sulfur ores and previously immobile U+4 (PARADIS ET AL., 2016).	H	Understanding sources of nitrate is important for assessing U mobility.
Gross alpha/beta		Standard screening method for radioactivity; parameter measured at site.	H	Required constituents.
Radium isotopes	Alpha-emitting isotopes of Ra (226Ra and 228Ra)	Radium 226 is in the U-238 decay series. Radium 226 has a half life of 1600 years and decays into radon gas. Radium 228 is in the thorium-232 decay series. Radium has a half life of 5.75 years. Radium 226 is a good indicator of waste water contamination from mines and mills (Kaufman et al., 1976).	H	Identify natural and anthropogenic contaminant.

Radon-222	Radon-222	Radon 222 is a decay product of Radium 226. High radon-222 has been associated with fault locations and uranium sources.	H	Radon-222 is a health hazard.
Uranium isotopes	U-234, U-235, U-238	There are three main isotopes of uranium (U-234, U-235, and U-238). U-238 is a weakly radioactive metal, and contributes to low-level background radiation in the environment. U-238 has a very long half-life of 4.47 billion years. Enriched U-235 is used as fuel in nuclear reactors and in nuclear weapons. Depleted uranium, which is poor in U-235 but rich in U-238, is used for commercial purposes. Uranium is common in specific types of igneous, metamorphic, and sedimentary rocks. Recent research indicates that increased concentrations of uranium in groundwater are caused by mobilization of uranium present in soil with irrigation waters containing bicarbonates. Also, nitrate can mobilize uranium through a series of bacterial and chemical reactions. Groundwater in the basin unaffected by mining has been found to have 234U/238U values ranging from 1.5 to 2.7. Ratios exceeding unity (secular equilibrium) result from alpha recoil of solid-phase 238U over geologic time causing the 234U daughter to be placed in favorable leaching sites. As ore bodies were dewatered, increased availability of oxygen caused uranium to dissolve rapidly without preference to 234U over 238U.	H	Identify natural and anthropogenic contaminant.
Stable isotopes of water	2H/1H, 18O/16O	Assessment of recharge conditions, fractionation processes such as evapotranspiration, and sources of water.	H	Water affected by evaporation of tailings water from LTP can be identified.
Sulfur isotopes of sulfate	δ34S, δ32S	Sulfur reactions that are involved with U mobilization. Availability of pyrite and sulfur oxidation can impact U mobilization. These processes are visible with 32S and 34S ratios.	L	There is some evidence of gypsum availability in geochemical reactions. Liberation of oxygen from dissolution of gypsum could enhance U mobilization.

Nitrogen isotopes	$\delta^{15}\text{N}$ of NO_3 , $\delta^{14}\text{N}$ of NO_3 , $\delta^{18}\text{O}$ of NO_3 , $\delta^{16}\text{O}$ of NO_3	Theoretically, identify nitrate controls on U mobilization. Denitrification processes can mobilize U and nitrogen isotopes can identify denitrification processes.	L	There are several sources of nitrate at the site including tailing operations and local septic systems.
Carbon isotopes	$\delta^{13}\text{C}$ of DIC, $\delta^{13}\text{C}$ of DOC, $\delta^{12}\text{C}$ of DIC, $\delta^{12}\text{C}$ of DOC	Useful for identifying carbonate reactions and carbon dioxide influences on chemistry. Carbonate is an important factor in U mobilization. Carbon 14 has a large half life and is used to date very old waters. Groundwater in study area may contain a mix of old and new waters and this would help identify bimodal ages.	M	The alluvial system has carbonate waters that may promote U mobilization. Carbon isotopes may be useful for identifying mixing in Chinle.
Carbon isotopes	Carbon-14		H	Chinle waters may contain a mixture of old water.
Dissolved gases	N_2 , Ar, CO_2 , CH_4 , O_2	Useful for looking at recharge conditions at time of water entering the subsurface.	L	Local and regional recharge may be distinguishable with measurements of dissolved gases. Measurements also provide additional check on oxygen and redox state.
GW dating: Tritium/Helium-3	Helium, Neon, $^3\text{He}/^4\text{He}$ with tritium by ^3He ingrowth	A primary age dating method for recent (60 years) water. Peak TU is in late 1950's-early 1960's. Age is calculated from parent/daughter decay of ^3H and ^3He .	H	Selective wells be analyzed to assess recharge rates and time of travel. Understand formation of mixing zones in the Chinle and help tag U concentration to general ages of recharge.
CFCs	CFS	A primary age dating method for recent (40 years) water. Peak is in late 1980s.	H	Will be used as a check on tritium/helium ages at a subset of wells.
Helium-4	Helium, Neon, $^3\text{He}/^4\text{He}$ with tritium by ^3He ingrowth	Screening tool to assess terrigenous Helium influence on tritium-helium dating.	M	Selectively analyzed constituent in Chinle waters.

2Al, Sb, As, Ba, B, Be, Cd,
Cr, Co, Cu, Fe, Li, Pb, Mn,
Hg, Mo, Ni, Se, Si, Ag, Tl,
U, V, and Zn.

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